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## **A neuroanatomical approach to exploring organizational performance**

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### ***Abstract***

Insights gained from studying the human brain have begun to open up promising new areas of research in the behavioural and social sciences. Neuroscience-based principles have been incorporated into areas such as business management, economics and marketing, leading to the development of artificial neural networks, neuroeconomics, neuromarketing and, most recently, organizational cognitive neuroscience. Similarly, the brain has been used as a powerful metaphor for thinking about and analysing the nature of organizations. However, no existing approach to organizational analysis has taken advantage of contemporary neuroanatomical principles, thereby missing the opportunity to translate core neuroanatomical knowledge into other, non-related areas of research. In this essentially conceptual paper, we propose several ways in which neuroanatomical approaches could be used to enhance organizational theory, practice and research. We suggest that truly interdisciplinary and collaborative research between neuroanatomists and organizational analysts is likely to provide novel approaches to exploring and improving organizational performance.

**Keywords:** neuroanatomy, organizations, organizational performance, interdisciplinary research

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## 1 INTRODUCTION

Organizational analysis - the study of organizations as entities within an environment, their social structures, technologies, cultures, physical structures and processes (Hatch & Cunliffe, 2006) - is one of the most complex yet important areas of business and management research. Many different approaches have been employed to assist our understanding, and improvement, of organizations and their performance. Several of these have used comparisons with other entities or explanations – often in the form of a metaphor or analogy - as a means to try and convey images or concepts associated with an organization or organizations.

One of the most significant recent advances in our understanding of organizations and organizational performance has stemmed from comparing organizations to biological organisms. As Morgan (2006) puts it, we find ourselves thinking about organizations as artificial “living systems”, existing in a wider environment on which they depend for the satisfaction of various needs. This awareness has led to a focus on understanding the principle that organizations, like organisms, are “open” to their environment. Thus, organizations need to be able to monitor, as well as respond appropriately and rapidly to, changes in their internal and external environments to maintain homeostasis (their primary ‘physiological’ state). Imbalance resulting from an inability either to sense or respond to changes in internal and/or external environments can be potentially disastrous for an organization – resulting in ‘strategic inertia’ (the inability to generate commitment), ‘strategic dilution’ (the inability to provide leadership) and/or ‘strategic drift’ (the inability to focus on where the organization is heading) (Freedman, 2003). The detrimental consequences of ‘strategic drift’ have been identified in companies experiencing rapid change (c.f., Pauwels & Matthyssens, 2003) and also in some extreme cases across an entire industrial sector (e.g. the US auto industry, including such well-known companies as *General Motors* and *Ford of America* (c.f., Womack et al., 2007)). Individual organizations with enhanced sensing capacities and capable of adapting themselves to best fit their current and – more importantly - future operating environments are therefore likely to be those that we refer to as high-performing organizations, who will be ‘superior’, gaining competitive advantage over their rivals and in the process survive and prosper (c.f., McKnight et al., 2001; Christensen et al., 1998; Venkatraman & Ramanujam, 1986; Hall, 1980).

These fundamental insights have led some organizational analysts to consider the human brain as a useful metaphor for thinking about the nature and performance of organizations. In 1972 Stafford Beer published what in many respects can be regarded as the first serious attempt to devise a coherent if eclectic model of organizational control (Beer, 1972). Based on physiological principles derived from studies of neuronal function and dissatisfaction with synthetic electronic brain models (such as Ross Ashby’s ‘Homeostat’ and Grey Walter’s ‘Tortoise’) (Asaro, 2006), his concern lay primarily with developing and extending the application of cybernetics into the realm of management through the derivation of a systemic model of control – eventually to take the form of the highly influential ‘Viable System Model’ (VSM) (Christopher, 2007). More recently, the brain metaphor has been used to draw attention to the importance of information processing, learning and intelligence, providing a frame of reference for understanding and assessing organizations (Morgan, 2006). In terms of organizational performance, this metaphor-based prognosis suggests that organizations should foster moves toward ‘holographic organization’ – as team-based and client-centred self-organized learning systems that place primary emphasis on being open to enquiry and self-criticism (c.f., Nonaka & Takuchi, 1995). Other uses of the brain metaphor tend to be more partial, for example, in assisting with the generation of flexible production system models (Garud & Kotha, 1994).

The brain-based metaphor has also been employed with respect to “softer” aspects of neuroscience, such as cognitive mapping (Tegarden & Sheetz, 2003) and the notion of contemporary organizations as so-called ‘intellectually impaired bureaucracies’ (Ambrose, 1995). Similarly, the notion of memory as applied to organizations (‘organizational memory’ or ‘organizational remembering’) has taken advantage of brain-based metaphors, leading to the use of terms such as ‘the brain-based organization’ (Walsh & Ungson, 1991; Harari, 1994; Feldman & Feldman, 2006). Thus, the potential benefits that could result from awareness of, and adoption of biological principles adapted from, such brain analogies are well recognised: “Today, knowledge - or more colloquially, brainpower and intelligence - has become the key determinant for economic and business success” (Harari, 1994).

That brain-based approaches can be valuable beyond their use as a metaphor can be found from other fields of research. For example, neuroscience-based principles have been successfully adopted in order to develop a new field in microeconomics – ‘neuroeconomics’. As Camerer et al. (2004) put it, neuroeconomics uses knowledge about brain mechanisms to inform economic theory by opening up the ‘black box’ of the brain, much as organizational economics opened up the theory of the firm with the introduction of organizational behaviour. The principal concern of this approach is with bettering our

understanding of individuals' preferences and preference-seeking strategies and their decision-making processes (McCabe, 2003). More contentious developments have seen the application of functional neuroimaging to market research and marketing science (what has come to be called 'neuromarketing' (Lee et al., 2007)) and the application of neurobiology to gambling addiction (the so-called 'dopamine hypothesis' (Melis et al., 2005; Vrecko, 2008)).

The most recent development of relevance to our paper has seen the emerging branch of cognitive neuroscience that brings together social psychology with neuroscience - social cognitive neuroscience - and its application to organizations (Senior & Butler, 2007). At its core is an understanding of the relationship between the brain and social interaction, in this case to the study of human behaviour in, and in response to, organizations - what has been termed 'organizational cognitive neuroscience' (Butler & Senior, 2007). Here the focus is on the neuroscience of social interactions at the social level and the need to understand the motivational and other social factors that drive behaviour and experience in the real organizational world rather than on organizational performance *per se*.

In this paper, we propose a new theory-informed and interdisciplinary approach to build on the use of the brain as a metaphor/analogy for understanding the nature and performance of organizations, incorporating long-standing and recent neuroanatomical principles underlying the structure and function of the brain into organizational theory and research. Much of the impetus for this approach has come from the fundamental insight that the anatomical arrangement of the brain shares many of the same constraints and demands that are faced by contemporary organizations, including: costs and efficiency (how much energy provision and blood flow are required?), space requirements (how much space in the skull should the brain really have?) and return on investment (how much could be gained by making the brain 5% larger and/or faster?).

Our goal in writing this paper is to highlight the significant interdisciplinary and collaborative potential that exists for sharing insights and approaches between neuroanatomical research and research on organizational performance. In our view, such a project - what we term 'neuroorganizational research' - like that of the development of 'organizational cognitive neuroscience' noted above, lies beyond the capacity of either neuroanatomists or organizational analysts to pursue independently since the nature of the problems identified are beyond the scope of either discipline (Klein, 1990). Our hope is that the neuroanatomical principles detailed below - purposefully simplified - will serve to highlight and stimulate new collaborative research avenues for neuroanatomists and organizational researchers alike. Whilst most of the organizational examples referred to relate to service organizations in the transport industries (reflecting the research interests of the co-author), we envisage that neuroanatomical principles could be of potential benefit for organizations of all types and sectors. Moreover, the belief that organizations are *individual* living organisms that have to be best suited to their local environment to survive and prosper is our fundamental working assumption (c.f. Morgan, 2006) - one set of 'rules' may work for one and not for another. Organizations are as individual as each of us, just like our brains.

The rest of the paper is divided into five main sections. In each section we highlight a different neuroanatomical concept or approach that may be of benefit for use in organizational research, including research ideas and possible topics.

## **2 STRUCTURAL SUBDIVISIONS IN THE BRAIN AND IN ORGANIZATIONS**

In this first section, we outline several existing structural (e.g. anatomical) similarities that link brains and organizations and suggest simple ways in which the adoption of basic neuroanatomical approaches could be used to better define and analyse the performance of organizations.

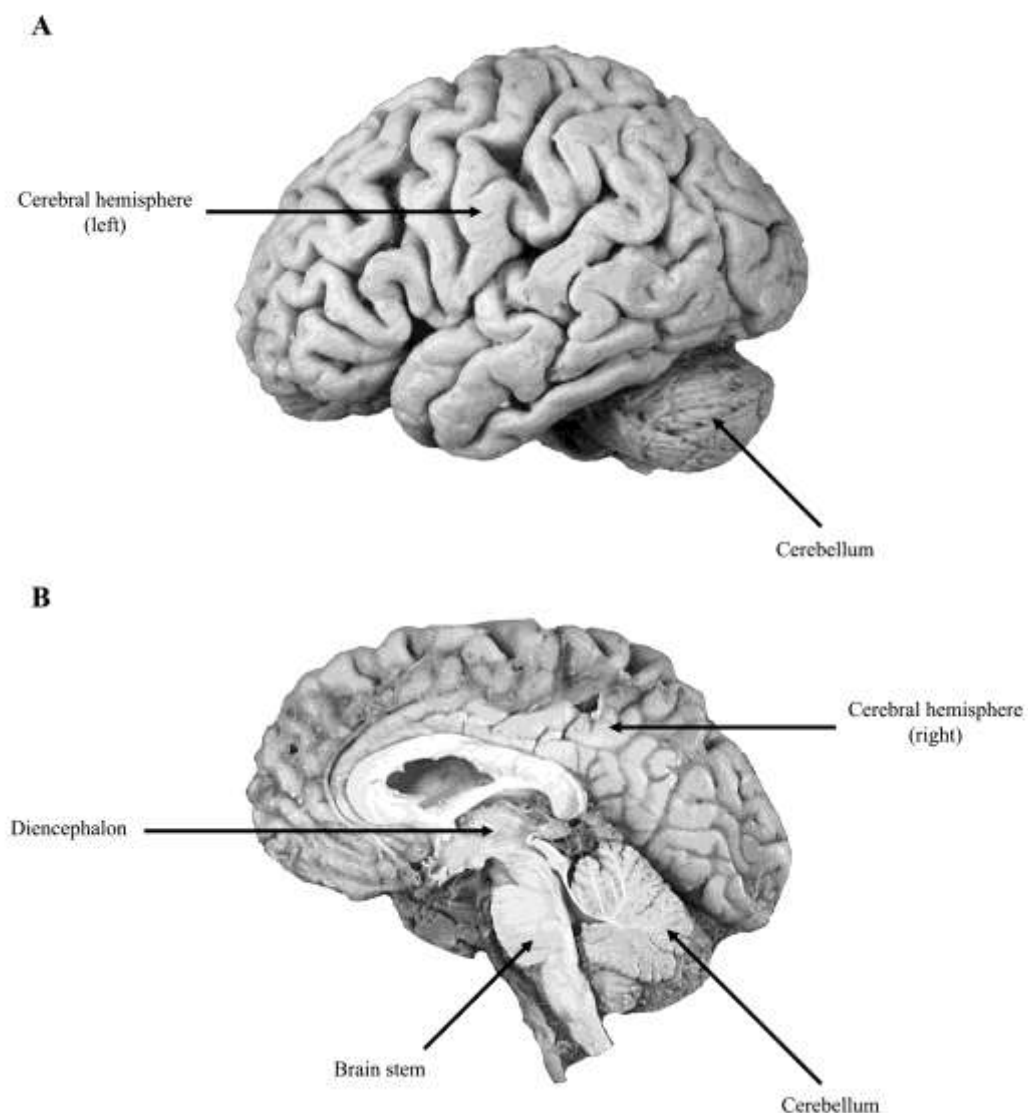
Many previous studies using the brain as a metaphor for organizational purposes have tended to take a simplistic approach, viewing the brain as a single homogeneous machine, capable of processing large amounts of information and undertaking many complex tasks simultaneously. However, detailed neuroanatomical investigation of the brain reveals a rather different entity, characterised by discrete structural units, interconnected via an astonishingly complex yet logical series of 'cables'. The human brain is therefore subdivided into a number of distinct anatomical regions, each defined by their appearance and/or main biological function(s). The main classical structural subdivisions of the brain are shown in Figure 1 and include the cerebral hemispheres (including the cerebral cortex), diencephalon, brainstem, and cerebellum (for a more in-depth overview of basic human neuroanatomy, see Crossman & Neary, 2005).

The neuroanatomical approach to understanding the brain takes these structural building blocks as its basis, from which more in-depth investigations can be undertaken to try and uncover its myriad of functions. In a similar way, contemporary organizations can be viewed as a set of discrete entities or

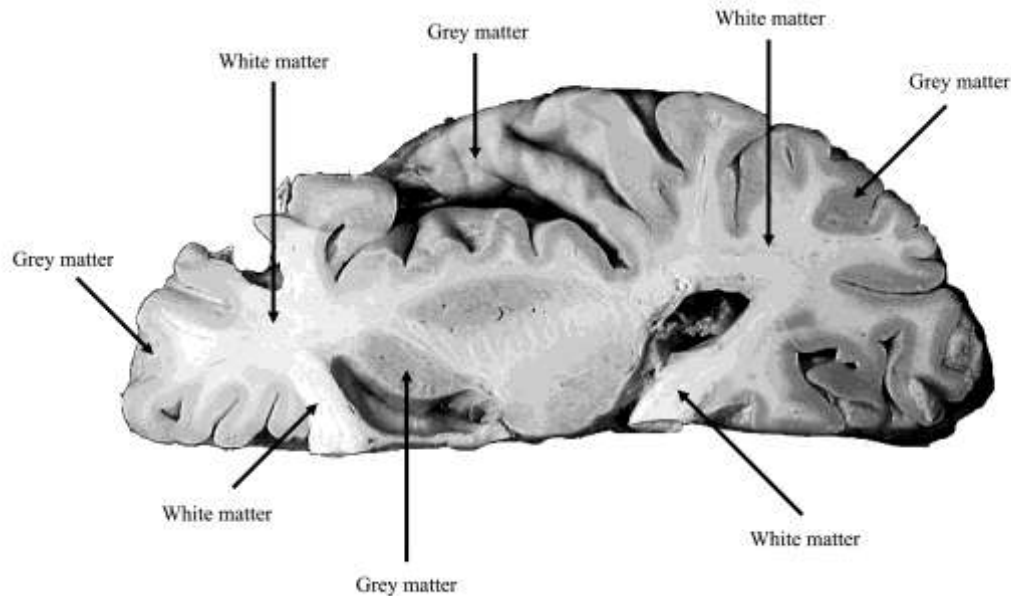
building blocks as they tend to have a series of distinct business units, often distinguishable on a physical and/or functional basis (e.g. sales, R&D, production, head office).

Importantly, however, it is the information that comes from understanding the patterns of network connectivity within and between distinct brain structures that has provided the real contemporary insights into how brain structure influences function and therefore performance. Regions of grey matter - shown in Figure 2 - are formed by collections of nerve cells (neurons), more often than not performing a specific function or set of closely related functions. Some of the most notable grey matter accumulations in the cerebral hemispheres include the primary motor cortex and primary somatosensory cortex, involved with the initiation and regulation of muscle contraction and the perception of general sensory stimuli (e.g. discriminative touch) respectively.

**Figure 1: Gross anatomy of the human brain and its major constituent parts: A - Lateral (external) view of the left side of a whole human brain annotated to indicate the location of major anatomical subdivisions; B - Medial (internal) view of the right half of a human brain cut in median sagittal section, highlighting other major anatomical subdivisions.**



**Figure 2: Photograph of horizontal section taken through one half of a human brain. Note the clear distinction between regions of grey matter and regions of white matter.**



In the diencephalon, the major grey matter region is the thalamus, a roughly egg-shaped structure sitting beneath each of the large cerebral hemispheres, playing a critical subconscious role in receiving and distributing almost all sensory information coming in from throughout the body. In contrast, white matter regions of the brain form a critical myriad of connections linking grey matter regions to one another (Figure 2). A good organizational equivalence for the role of white matter in the brain, and its relationship to grey matter, is that of internal communication - for example, connectivity between the business units of a global organization using high-speed information and communications technology (ICT). If an organization's offices in New York and London are thought of as being equivalent to two distinct regions of grey matter in the brain, then the streaming of data via fibre optic cables and remote satellite is equivalent to the white matter. White matter therefore provides the all-important communication channels through which different functional units of the brain interact, facilitating rapid (almost in 'real time') and accurate transfer of information throughout the entire organ. As a result, the importance of white matter integrity to overall brain function and performance cannot be overemphasised: for example, the specific breakdown of brain regions involved in communication is known to play an important role in debilitating conditions such as stroke and multiple sclerosis (Ferguson et al., 1997; Dewar et al., 1999; Wishart et al., 2006).

The large-scale connections within the brain (white matter tracts) are readily identifiable on gross brain dissections (see Figure 2) and have led to detailed structural maps of the brain (e.g. Wakana et al., 2004). However, recent breakthroughs in neuroanatomical research have allowed researchers – using novel brain imaging techniques (Catani, 2006; Lichtman et al., 2008) – to begin to piece together more subtle, yet no less influential, 'wiring' patterns of the brain. This neuroanatomical research has been key to our contemporary understanding of the structure and function of the brain, as mapping refined physical and functional neural circuits has allowed us to account for brain activity and observe how alterations in discrete regions of the circuitry can lead to dysfunction of the brain.

That a similar structural arrangement can be found in organizations becomes more obvious when examining how groups of individuals become ordered within an organization and the routes of communication they use. Many organizational subdivisions are directly equivalent to grey matter nuclei in the brain as they often contain large numbers of individuals (equivalent to neurons in the grey matter), more often than not focused on performing a specific task or role. White matter equivalents include the internet, email, telephone, meetings, video conferencing, etc. As with the brain, the

integrity and efficiency of formal and informal intra-organizational communication links are known to be similarly important for the successful function of high-performing organizations (Adams et al., 1993; Lievens & Moenaert, 2000; Marshall et al., 2007). Thus, a mapping approach akin to ‘business process mapping’ (Kaplan & Norton, 2000), but based on neuroanatomical principles and employing neuroanatomical terminology rather than process modelling methods like ‘Six Sigma’, is likely to provide a sounder basis from which to develop a coherent and relevant understanding of an organization’s structure and functions, as well as providing the opportunity to identify regions of potential weakness or dysfunction in its connectivity and performance.

Whilst this approach may seem rather unproblematic, gaining the required information to build a ‘grey and white matter wiring diagram’ for an organization may not be so simple. For example, one of the key concepts underlying connectivity within the brain is that of the segregated nature of information coding, transmission and decoding (Ciborra, 2001a). Communication channels in the brain are almost always divided into those with *input* functions (sensory pathways carrying information about the internal and external environment towards the brain), *modulating* functions (short, local networks allowing communication between adjacent regions of grey matter), or *output* functions (motor pathways carrying effector information away from the brain and out into the body, leading to contraction of muscles). These different modalities can be readily distinguished from one another in the brain as a result of the selective use of different chemical signals (neurotransmitters) released by distinct subpopulations of neurons. In the organizational context, such clarity is less readily observed, although no less important. For example, individual business units require a clear understanding of the location and nature of incoming information versus intra-unit communication channels and outgoing communications. However, the contemporary world of rapid and integrated communications technology and media (e.g. the internet, intranet, wire-less communication) makes deciphering the source and relevance of information a time-consuming and sometimes overwhelming chore, contributing to the phenomenon of ‘information overload’ (Eppler & Mengis, 2004). Whilst it can be argued that such clear subdivisions are rarely the norm in most organizations (Kaplan & Norton, 2000), a good example of where this approach can be identified in organizational practice is provided by the organization of air traffic control services (Smolensky & Stein, 1998) – an intensely information-rich and communications-critical operating environment, where there is an unambiguous, overriding and universally agreed goal (the safe arrival of aircraft). Studies of such organizations and operating environments may therefore provide a good starting point for future research investigating the potential for incorporating neuroanatomical principles into the structure and function of high-performing organizations.

### 3 ‘DOING’ INDIVIDUALS AND ‘SUPPORTING’ INDIVIDUALS

In this second section, we examine the way in which cellular neuroanatomy (investigating the identity, relationships and function of individual cells within the brain) has provided novel insights into the structure and strategy of the brain and outline potential organizational equivalences.

One of the key principles of cellular neuroanatomy is that the brain consists of two main populations of cells: neurons and supporting cells (glial cells). The electrically excitable neurons are the primary ‘doing’ cells of the brain. Their cell bodies are resident in grey matter whilst their long thin processes (axons) pass out into the white matter in order to establish contact with cells in other regions of the nervous system. These axon processes end at specialised chemical communication points known as ‘synapses’, from where they pass on their information to the next cell in the network (known as the post-synaptic cell). Glial cells, in contrast, assist neurons to improve their performance by providing nourishment, shielding them from the immediate internal environment, and moderating their exposure to potentially damaging chemicals and environments. They are present throughout the grey and white matter, but in the white matter play an important role in ensheathing (myelinating) the axons of neurons to increase the speed at which they conduct electrical impulses via saltatory conduction. Importantly, this very clear delineation of cell type and function is set, and normally cannot be reversed after each cell has undergone development and maturation. Thus, ‘doing’ neurons are specialised precisely for that function and do not have to worry about supporting any other individuals. ‘Supporting’ glial cells are the complete opposite, sustaining other cells wherever they can but without the requirement or ability to directly generate or transmit any information.

The importance of delineating cells with a ‘doing’ function from those with a ‘support’ function suggests that individuals within an organization (akin to cells within the brain) may also perform better when equipped with the specialised skills and resources to perform one of these roles, rather than trying to do both. There are numerous examples where individuals within organizations have attempted to

take on both roles, leading to work over-load, a lack of specialisation, and the threat of failure. A particularly apt example is provided by the iconic US low-fare, high-value airline *JetBlue Airways* and its founder, chairman and CEO, David Neeleman. According to one seasoned industry observer (Straus, 2009), the carrier's highly publicised operational and financial turbulence in early 2007 could be attributed in no small part to Neeleman's attempts to both steer the airline's future development (in his role as chairman) as well as maintain operational control (as CEO). Within the space of a few months, *JetBlue* effectively restructured its entire operation. A *JetBlue* spokesperson told Straus that "The big difference now is that David simply could not do both. He could not run the day-to-day and also look three, five, 10 years out into the future. This change allows him to do that. ... Dave [Barger's] strength [as the newly appointed CEO] is running an airline. He knows what it takes to restore JetBlue's operational integrity."

Despite the distinct identity and roles of neurons and glia in the brain, one of the most important breakthroughs in cellular neuroanatomy research has been to highlight the requirement for a close working relationship between the two cell types in order to achieve optimal performance (Sherman & Brophy, 2005). Changes in the status and/or function of one cell type are almost always immediately detected by the other. Breakdown of these mutual relationships results in altered function and anatomy in the nervous system and is thought to be play an important role in several neurodegenerative conditions, including motor neuron disease (Boillee et al., 2006; Nagai et al., 2007). From an organizational perspective, this suggests that whilst individuals with 'doing' or 'supporting' functions may benefit from being specialised towards one of these roles, they should never isolate themselves from individuals in the same work team or organization that perform the converse role. Whilst it may be tempting to view 'doing' individuals as the most important in any organization, and therefore in some way superior to 'supporting' individuals, the cellular neuroanatomy of the brain suggests that mutual respect and support between the two types of role is likely to be important for optimum performance. It is therefore possible to envisage a neuroanatomical approach being beneficial to understanding the identity and roles of an individual within an organization by coding them as primarily a 'doing' or a 'supporting' individual. The awareness of this identity could then be used as a tool for managing workload and the type of work for any given individual, and could also be used to ensure good communication links between doing individuals and supporting individuals.

These neuroanatomical insights also lend support to the notion that, on the one hand, bureaucratic command-and-control type structures are less than ideal and should be avoided wherever possible, with small interdependent organizational units being preferred, and, on the other, recognizing that all personnel should be integrated into the workings of the organization with a clearly defined role where they are trusted, respected and inspired. Two organizations that it could be claimed currently integrate the symbiotic 'doing' and 'supporting' functions in a highly transparent form are *The Walt Disney Company* and *IKEA*. The lionization and reinvention of *Disney* and the 'Disney approach' under the stewardship of Michael D Eisner have been well documented (c.f., Disney Institute, 2001; Capodagli & Jackson, 1999) but not uncritically (c.f., Bryman, 2004); and *IKEA*, the Scandinavian-based low cost-high quality furniture retailer – the largest in the world with a growing global presence – is beginning to assume a similar iconic status (Kotler, 1999; Edvardsson and Enquist, 2002). Such high-performing organizations may therefore provide good case study material for further investigations into existing and potential future synergies between organizational and neuroanatomical theories and practice.

#### 4 DEALING WITH INFORMATION OVERLOAD

In this third section, we highlight the main neuroanatomical approaches used by the brain in order to overcome one of the major problems shared by brains and organizations alike: how to deal with information overload. Receiving, integrating and highlighting important information collected from both internal and external environments is undoubtedly one of the core functions of the brain. Organizations face a similar complexity and wealth of information available to them, which is only likely to increase over the coming years due to the expansions in, and demands of, ICT. And yet, organizations that are successful are generally considered to be those that have a 'bias for action' (Peters & Waterman, 1982): where communications are of the essence and they are best capable of collecting, processing and responding to information from their internal and external environments (Ciborra, 2001b). Organizations therefore face very similar problems to the brain, being required to process important information rapidly, efficiently and effectively, whilst not losing sight of less specific (albeit potentially no less important) changes occurring in their wider internal and external environments. ICT provides the required speed of response in many organizations, but does not guarantee its effectiveness (Eppler & Mengis, 2004). Any strategy that has the potential to improve the



abilities to sense, predict and assimilate changes in an operating environment is therefore likely to be advantageous.

The anatomical arrangement of the human nervous system (and here we are deliberately extending beyond the boundaries of the brain to incorporate the spinal cord and peripheral nerves) provides two distinct ways of dealing with this problem: reflex arcs that are capable of eliciting repeatable and rapid responses to important stimuli (e.g. pain or excessive heat); and the ability to deal with information at a conscious or subconscious level, allowing some functions to proceed with the minimum of input or resources from more complex and resource-demanding conscious areas of the brain.

The presence of reflex arcs within the nervous system allows rapid, stereotyped responses to occur following an important, narrowly-defined, non-strategic (i.e. not requiring any long-term planning) sensory stimulus (e.g. rapid lifting of the foot in response to pain resulting from treading on a sharp object). These responses occur locally within the spinal cord, facilitating a stereotyped response over a much shorter timescale than if the sensory information had to travel up to higher 'conscious' regions of the brain, before being processed, assimilated and a decision arrived at as to how to proceed. The presence of reflex arcs therefore bypasses the requirement to sift through large volumes of information that are constantly coming in from all types of different sources in order to identify, process and respond to a critical stimulus that would benefit from a rapid response. The reliance on integrated management information systems in the contemporary organization provides the opportunity to implement similar reflex arcs in the organizational context, allowing much more rapid responses to key incoming stimuli without requiring 'decisions' to be made prior to a response (c.f., Larsen & Leinsdorff, 1998). However, the incorporation of neuroanatomical principles underlying the reflex arc into such management information systems might improve their performance.

The cellular arrangements of the nervous system that permit a rapid and stereotyped reflex response are based around the existence of discrete populations of individual neurons in the spinal cord that are specifically tasked, positioned and connected to detect pre-defined 'important' events coming in from the periphery (e.g. pain) and which also have the 'authority' to initiate a response (e.g. movement of the limb away from the painful stimulus) without prior approval from higher centres in the brain. Building such an arrangement into organizational structure and strategy, most likely by incorporating this approach into pre-existing integrated management information systems, may therefore confer similar reflex abilities.

In organizational terms the basis of such an approach may already exist - albeit without the clarity provided by the neuroanatomical framework - corresponding to the practice of pushing responsibility down the line, combining firm central direction with maximum individual autonomy (what has been called 'simultaneous loose-tight properties' (Peters & Waterman, 1982)), and reflected in the obsession with layering (i.e., removing intermediate levels of managerial responsibilities wherever possible). This approach is currently the *sine qua non* of two of today's most successful business operations - the 'production system model' of the Japanese car maker *Toyota* (Liker, 2004; Dahlgard-Park & Dahlgard, 2007) and the 'fast aircraft turnaround model' typified by the low-fare high-value US carrier *Southwest Airlines*. The 'Southwest model' (Flouris & Oswald, 2006), now replicated in part by the majority of low-cost airlines around the world, is based not only on high asset utilisation (aircraft operations) but more importantly on the development of high-performance relationships that characterise the organization (Gittell, 2003). These characteristics suggest that the devolution of decision making - in response to a specific and defined set of environmental stimuli - down to the level of individual workers within an organization is a good way to improve rapid, efficient and effective responses to key, stereotyped stimuli relevant to an individual organization (e.g. competitor price cuts, supply chain problems, growth in customer demand).

For information and inputs that require more processing and integration than those which elicit a simple reflex response, the brain resists information overload by channelling information accurately into discrete anatomical regions operating at conscious or subconscious levels. The ability to channel information into regions of the brain that do not normally require conscious control or awareness allows many core survival functions required for life support to take place with a minimum of effort. For example, subconscious regions of the brain such as the brainstem are constantly monitoring and responding to changes in both internal (heart rate, blood pressure, temperature, etc.) and external environments. Only when the magnitude of change in any of the monitored parameters broaches a critical level does an 'awareness' of the information reach an individual's consciousness. This arrangement frees up conscious areas of the brain, such as the cerebral hemispheres, to undertake more complex information assimilation, decision-making and planning activities. Interestingly, it is these conscious areas of the human brain that have undergone massive evolutionary expansion, allowing the development of our higher cortical functions (Kriegstein et al., 2006).

From an organizational perspective, the potential benefits of subdividing information processing and decision-making tasks into 'conscious' and 'subconscious' areas appear to be worthy of serious further investigation. Examples of where this kind of approach has been shown to work effectively include high-performing organizations like *Toyota* and *Ikea* that combine the attributes of a simple structural form and a 'lean' management style with firm central direction and maximum individual autonomy (Stadler, 2007) – but, in this case, with a focus not only on developing autonomy among individuals but also on their internal entrepreneurship and innovation capabilities. This approach highlights one potential way to allow such autonomy and individual innovation within an organization, without a loss of control or focus: an obsession with the customer. Nowhere is this better illustrated than in an industry-leading service-driven company like *Southwest Airlines*, structured on the basis of high-performance relationships that are built on 'relational coordination' (Gittell, 2003). For example, *Southwest's* Customer Service Commitment states that: 'We tell our Employees we are in the Customer Service business – we just happen to provide airline transportation' (SWA, 2009). *Southwest's* remarkable success can be measured by the fact that they are the only airline ever to have recorded year-on-year profitability since their inception in 1971 and to have achieved the best cumulative consumer satisfaction record of any US airline. This has been achieved with low staff turnover rates, more flexible work arrangements than competitors and a high level of unionization (Gittell, 2003; Flouris & Oswald, 2006).

The use of a neuroanatomical approach may therefore be of benefit for assisting other organizations to conceptualise and implement similar structures and practices. Here, core housekeeping operations equivalent to 'subconscious' functions should be able to progress with a minimum of disruption and effort, without reliance on constant input from 'higher' ('conscious') centres of the organization. Similarly, individuals and managers connected with strategy and planning would not expend time and energy on 'lower-level' issues, unless something went wrong and required intervention. However, neuroanatomical research has highlighted that this approach – separating the 'conscious' and 'subconscious' areas of an organization – does not imply that basic 'subconscious' business processes should not be carefully monitored and remain within the conscious psyche of the organization as a whole. Quite the opposite, as failure of 'subconscious' business processes often means failure of the organization. Rather, 'subconscious' business processes should be allowed to proceed without repeated interventions that rarely add significant value to the organization as a whole.

One likely consequence of adopting such an approach for an organization would be problems with directing relevant information towards conscious or subconscious centres. Once again, however, the brain has already developed a means to deal with this problem that could readily be transferred to the organizational context. The thalamus (the grey matter region located in the diencephalon - Figure 1), sitting beneath each of the large cerebral hemispheres, plays a critical subconscious role in receiving and distributing almost all sensory information coming in from throughout the body (Schmahmann, 2003). One useful analogy is to compare the thalamus to a central postal sorting office, where all mail consignments (sensory information) have to be brought before being sorted by address and sent out to their correct final destination. Information coming in from the body is therefore not communicated to the conscious cortex in a haphazard, randomly organized way, thereby reducing information asymmetry and mis-information. The presence of a similar central (but not necessarily centralised) information receiving/distributing centre could be provided to an organization by modifying and enhancing existing ICT infrastructures (see above; Monteiro & Hepso, 2001) or customer relationship management models (CRM) (Wilson et al., 2002), as they are often already established to collate and distribute important internal and external information (e.g. competitors' prices, internal supply chains, direct and indirect costs).

The ability to separate 'conscious' and 'subconscious' areas is also critical for undertaking the exceptional long-term planning and strategic thinking functions associated with the human brain. As a result of these attributes, the human brain has the ability not only to monitor and respond to the environment, but also to 'second guess' it, allowing plans to be made to influence internal and external environments rather than simply being forced to respond to changes in them. This ability is one that is highly sought after by organizations, forming the basis of much strategic planning and re-organization. Its locus is to be found in the twin themes of organizational leadership (especially the powers of visionary and transforming leadership (Bryman, 1992)) and organizational culture (in particular the ability to foster and engender creativity and innovation in the implementation of strategy). The adoption of a neuroanatomical approach to 'conscious' and 'subconscious' functions may therefore go some way towards conferring this ability. In particular, executive decision-making and planning processes in the human brain take place in regions of the cerebral hemispheres distinct from other areas responsible for conscious awareness of the environment (e.g. primary sensory cortex) and executing decisions (e.g. primary motor cortex), suggesting that the physical and intellectual separation of these

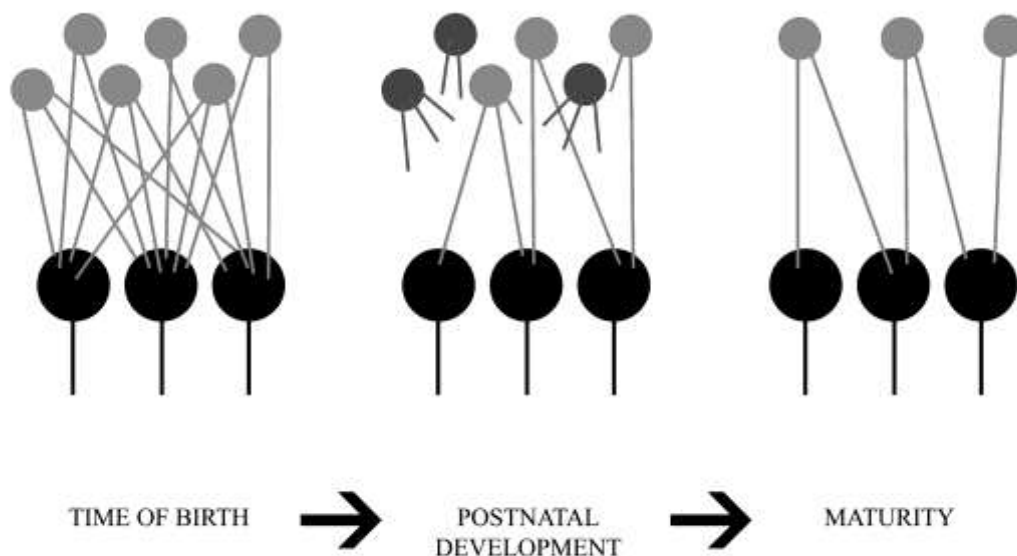
functions from the more mundane day-to-day tasks of running an organization would be beneficial. This approach is perhaps another instance where the high-performance relationships that underpin *Southwest Airlines'* leadership, culture and strategy (Gittell, 2003) contribute to its unique competitive advantage (Flouris & Oswald, 2006).

## 5 IMPORTANCE OF ENVIRONMENTAL EXPOSURE DURING DEVELOPMENT

In this fourth section, we examine how insights gained from studying the development of the brain might be useful for our understanding of the birth, growth and development of organizations. In particular, we discuss the importance of environmental exposure during the early stages of an organization's life-cycle: creation and growth. The developmental processes that the brain goes through to reach its final adult state are, just like organizations, highly complex and critical for the successful establishment of a fully-functioning organ. The importance of these early stages of development should not be overlooked, especially when they are known to play a significant role in determining the eventual 'mature' state and performance of both brains and organizations (Hensch, 2005; Wolpaw, 2006; Van de Ven, 1980; Quinn & Cameron, 1983).

The gross anatomy of the brain is established early on in pre-natal development, much as the plans and 'blue-print' for the general structure and strategy of a new organization (or new business unit within an existing organization) are often established well before the organization becomes a physical entity (Quinn & Cameron, 1983). However, the fine network of internal circuitry within the brain is only refined into its experienced, fully-functioning state by a process of gradual sculpting and re-wiring that occurs during critical periods of development after birth. During these periods, excessive and incorrect connections and pathways are pruned away – as shown in Figure 3.

**Figure 3: Schematic diagram representing the normal process of postnatal pruning of connections that occurs throughout the human nervous system shortly after birth.**



The removal of excess and/or incorrect connections, critical for establishing the fully-functional mature nervous system, is driven by a variety of genetic and epigenetic factors such as their relative levels of activity, the presence or absence of competing inputs for the same role, relationships of neuronal cells to their surrounding glial cells, and/or suitability for a specific function (Wyatt & Balice-Gordon, 2003; Low & Cheng, 2006; Freeman, 2006). As a result, the brain is prepared for its future tasks and challenges by moulding itself in response to the external and internal environments it becomes exposed to during the first weeks and months of its life.

The importance of environmental exposure is perhaps best illustrated by the effects of visual disturbances on the development of the primary visual cortex (the region responsible for conscious processing and awareness of visual information). It is well established that visual acuity in humans

develops substantially (improving roughly fivefold) over the first few months following birth, before fine-tuning the system over the ensuing six years (Maurer & Lewis, 2001). However, if the visual system is perturbed during this critical developmental period (e.g. by congenital blindness or cataracts) then the primary visual cortex fails to re-organise and arrange itself normally, and in some cases can even be taken over by sensory inputs coming from other modalities such as touch or sound (Maurer et al., 2005). As the individual matures, the ability of the brain to undertake remodelling and reorganization on such a large scale declines. Thus, the majority of experience-dependent learning needs to be undertaken, with accompanying resource allocation, during the early periods of an individual's life, as it cannot be adequately compensated for at a later date.

An understanding of the critical periods present during the successful growth and development of the brain, alongside an appreciation of the consequences of failure to provide environmental exposure during these periods, has potentially important insights for organizational development. Although many different models of the organizational life cycle (OLC) have been proposed (e.g. Lippitt & Schmidt, 1967; Miller & Friesen, 1980; Greiner, 1998), many share the concepts of organizational creation/birth and growth preceding maturity (Lester, 2004). Similarly, many models imply that a failure to undergo developmental processes required to establish a mature organization with a good environmental fit and the capacity to respond to important sensory stimuli results in the high numbers of companies that fail to last beyond 12 to 18 months from the time of their creation (Quinn & Cameron, 1983).

Of particular note, the high levels of resources available to the developing brain after birth (e.g. energy, number of contributing cells) have been found to be of critical importance, allowing the initial (pre-natal) over-elaboration of contacts and functions before subsequent post-natal sculpting occurs. Translation of these insights to the organizational perspective suggests that resource allocation during creation and early growth phases of the OLC is likely to be critical to success (Buenstorf & Witt, 2006). Thus, an organization looking to take advantage of neuroanatomical principles would require the ability to commit significant resourcing to ensure that, at its conception, it has *more* resources than may eventually be required. This is especially the case for 'softer' resources like management experience and commitment, time and creative space, as well as the more conventional resources of superior market intelligence, appropriate personnel, innovative products and services, efficient outputs and effective networks of inter-organizational connections (Lester, 2004). These facilitate the all-important freedoms to subsequently undergo 'developmental remodelling' in response to both internal and external environmental pressures and opportunities that are unlikely to be fully anticipated or predicted before launch. In this way, an organization has the potential to be more successful in its growth and early maturity phases because it has allowed itself to be shaped by the real pressures of the turbulent business world it inhabits, rather than trying to 'shoe-horn' a 'one trick pony' or 'one size fits all' offering into a predetermined fixed structure, planned before creation, into a business environment where it does not ideally fit.

An illustration of the potential effectiveness of this approach to 'developmental remodelling' is provided by the evolution of *JetBlue Airways* and its 'value-based model' (Flouris & Oswald, 2006; Fiorini, 2002). Neeleman, *JetBlue's* founder, having already experienced the trials and tribulations of starting a new airline – *Morris Air Service* – which was subsequently sold to *Southwest*, was then employed by *Southwest* during which the idea of *JetBlue* was born. The four factors which appeared crucial were: the prior experience gained when creating a minor airline; the valuable learning gained whilst at *Southwest*; the ability to attract and adapt mature airline talent to a new corporate concept prior to start-up; and finally, perhaps most crucially, the reflective evaluation of the reasons behind the failed growth strategy of the path-breaking low-cost US carrier *PEOPLExpress* (Wynbrandt, 2004; Peterson & Glab, 1995) – and a recognition of the resourcing requirements necessary for creating a value-based service: innovation (in the sense of 'doing things differently' to competitors), flexibility, speed of response and a sense of intimacy with employees and customers alike.

An apposite organizational illustration of the sort of 'developmental remodelling' that the brain undergoes is provided by the European low cost airline *easyJet*. In the early 1990s, its founder, Stelios Haji-Ioannou, saw the potential not only for a European version of the highly successful *Southwest Airlines* but the opportunity created by the liberalisation of European skies and the challenge that could be made to the high-cost incumbent airlines' dominance in key markets. As Kumar (2004) points out, the creation of *easyJet* was not simply a case of the right person being in the right place at the right time but, more significantly, the ability of Haji-Ioannou to develop a truly transformational initiative – a strongly marketing-led strategy based not on conventional market segmentation but on strategic segmentation. As both Kumar (2004) and Rae (2001) illustrate, *easyJet* as an organization, the '*easyJet* model' (Sull, 1999) and its founder – like Neeleman and *JetBlue* – have been the subject of and subject to a continuous evolutionary process of refining, sculpting and rewiring since its conception – perhaps a classic case of organizational fluidity and the importance of environmental exposure during

development and the resourcing implications that are a prerequisite for success. Today neither *easyJet* nor *JetBlue* bear much of a resemblance to their original organizational states (Kuemmerle, 1999). Such organizations may therefore provide ideal sources for case studies further investigating how neuroanatomical concepts regarding environmental exposure during growth and development may confer a competitive advantage in the organizational context.

## 6 THE IMPORTANCE OF RETAINING FLEXIBILITY

In this final section, we discuss how research highlighting the importance of flexibility within the mature brain might be useful for our understanding of the impact and importance of one specific facet of modern organizational research: organizational memory.

Whilst there is a considerable volume of literature detailing the existence and importance of organizational memory, and its roles in organizational learning and decision-making (Walsh & Ungson, 1991; Feldman & Feldman, 2006), many mature organizations are characterised by static structures and procedures that are unwilling and/or unable to remodel themselves in response to changing business environments and competitive pressures (Ambrose, 1995; Brown, 2004), resulting in the threat of 'strategic drift' or its realisation (Johnson, 1988; Larsen & Leinsdorf, 1998; Ciborra, 2001a). For example, the construct of 'network inertia' has been identified by Kim et al. (2006), referring to a persistent organizational resistance to changing interorganizational network ties or difficulties that an organization faces when it attempts to dissolve old relationships and form new network ties. McKnight et al. (2001) refer to the processes of 'creative destruction' that can accompany an organization's quest for survival in ultra-competitive markets like telecommunications in the Internet age. Thus, many organizations lack the core creative abilities possessed by the brain in order to break down and/or establish new connections, thereby conferring adaptability and 'learning' – organizational fluidity.

One way around this problem may be forthcoming from the adoption of neuroanatomical principles. Despite losing the ability to undertake large-scale developmental reorganization after the first few years of life (the reason why it becomes a lot harder to, for example, learn a foreign language the older you get), the brain retains the capability to adapt and remodel itself in response to more subtle stimuli, at the level of individual cells and circuits, throughout its entire life. This ability to undergo functional and structural remodelling is critical to undertake complex adaptive functions in the mature brain, such as learning and memory in response to changes in internal and external environments (Trachtenberg et al., 2002; Cooke & Bliss, 2006).

Importantly, it has been found that most of this plasticity occurs at the sites of connection and communication between neurons: the synapse. Individual synaptic connections are capable of being strengthened or weakened as well as created and lost. The basic principle underlying each of these processes is neural activity: the more functional neuronal circuits are utilised, the stronger the connectivity within it becomes and the more stable they become in the long-term. Thus, the ability to make, break, strengthen and weaken connections in the brain is critical for its function. These processes allow an individual to adapt constantly to the pressures and demands of their surroundings, making the most out of opportunities that become available. The requirement for making and breaking network connections within and between organizations in order to be able to adapt and respond to new and emerging opportunities and threats is supported by the findings of Christensen et al. (1998) into survival strategies in fast-changing industries (in this case, technological innovation in the rigid disk drive industry). Their analysis suggests that simple "first-mover advantages" and most of the postulates of the entry timing literature might not hold true in such industries. Although they claim that entry timing still has something to tell us about the success or failure of organizations in these industries, they propose the idea of a "window of learning" as a more accurate way of conceptualizing the importance of entry timing in fast-paced industries. It also strongly suggests that 'creatively intelligent' organizations capable of dynamic responses are likely to be those that succeed in uncertain business environments (Ambrose, 1995; Hart & Banbury, 1994; Hart, 1992).

Two organizations that it could be claimed exemplify this plasticity and ability to remodel their network connectivities in a highly creative and intelligent way are *Southwest Airlines* and *Virgin Atlantic Airways*. Like *Southwest*, *Virgin* has constantly over its 25-year life sought to gain a competitive advantage by differentiating itself from what it regards as complacent and conservative mainstream airlines. This differentiation strategy has been based on what has been called a 'value innovation' approach (Kim & Mauborgne, 1999). As Denoyelle & Larreche (1995) have put it, in its customer's eyes, *Virgin* represents a sense of value for money, quality, innovation, fun and a sense of competitive challenge. This is reflected in its corporate positioning and recruitment policy: 'Immaculate service and unrivalled quality are everything to us here at *Virgin Atlantic*. The high standards and experience of the people we hire has helped us become one of the world's most highly

rated airlines. In fact, whether you join us in the air, on the ground or behind the scenes, you'll need to be totally focused on delivering everything our customers have come to expect of us.' (VAA, 2009) In practice, over the years, this has required the airline not only to recruit personnel whose beliefs and personality are in alignment with its corporate values (Mitchell, 1999) but also to monitor customer feedback and then use that feedback as a basis for improving the customer experience on a constant and continuous basis. According to Denoyelle & Larreche (1995), *Virgin* looks for opportunities where they can offer something better, fresher and more valuable by moving into business areas where the customer has traditionally received a poor deal and where the competition is regarded as being complacent; it is proactive and quick to act. 'Because we're such a complex and rapidly evolving business, we expect all our people to be adaptable, quick thinking and people focused every day to contribute to our ongoing success.' (VAA, 2009) Unlike its principal competitors, *Virgin* relies heavily on the power of its brand image and supporting infrastructure: the highly visible and personal reputation of its charismatic leader, Richard Branson; a professionalized management style and structure based on empowerment and minimal layers of management; its dynamic network of influential business partners; a small number of directors in what is a privately owned company; no global corporate headquarters; and being one of a family of businesses in the *Virgin Group* (Denoyelle & Larreche, 1995; *Virgin Group*, 2009). Combe & Botschen (2004) contend that this illustrates what they call an effective use of 'process developmental strategy': a continuous process of 'learning by doing' when confronted by dynamic complexity, where obvious interventions produce non-obvious consequences and where the same action can produce dramatically different effects over different time horizons. They argue that the complexity of managing quality in a consumer-led service industry – which after all is what both *Virgin* and *Southwest* see themselves in – is further increased when there is continuous change in the external environment due to intense competition and changing customer needs. Flexibility and flexible response – the requirement for making and breaking network connections in order to be able to adapt and respond to new and emerging opportunities and threats – is clearly critical to organizational success.

However, gaining the creative ability to alter network connections and business processes within and between organizations is not as straightforward as it may seem (Grinyer et al., 1989). Attempts to adapt and remodel both organizational structure and strategy – to 'turnaround' an ailing company into a high performing organization – are often constrained by embedded (possibly even inherited) routines, rules and procedures, commonly based around technological constraints and/or organizational culture (Kim et al., 2006) or else a failure to close what has been called the 'strategy-to-performance gap' (Mankins & Steele, 2005). Such constraints often result in 'deadlocked organizations' (c.f., Nicholson et al., 1990) and, in some extreme cases, to a 'deadlocked industry' (Bryman et al., 1996). The neuroanatomical principles we have explored thus far may be of considerable utility to those organizations not conforming to the heights of 'corporate excellence' since our core neuro-organizational equivalences offer the ability to 'diagnose' organizational problems like 'strategic drift' (Johnson, 1988) and 'intellectually impaired bureaucracies' (Ambrose, 1995). For example, it is worth noting that recent advances in neurodegenerative research have shown that synaptic connections (communication sites between individual nerve cells) are often disrupted at very early stages of disease in the brain (Wishart et al., 2006). This suggests that connectivity between and within affected brain regions in human neurodegenerative disease is affected very early on, *before* the onset of more major symptoms. Approaches to improving and maintaining communication links within organizations, such as those detailed in earlier sections of this paper, may also provide useful monitoring tools with which to identify and rectify early 'symptoms' of malfunction or breakdown in key business processes prior to the onset of a loss of critical flexibility and the ensuing 'strategic drift'.

## **7 CONCLUSIONS & IMPLICATIONS FOR FUTURE RESEARCH**

In this paper we have proposed several ways in which neuroanatomical approaches could be deployed to enhance our understanding of how organizations function and perform. We suggest that interdisciplinary research between neuroanatomists and organizational analysts is likely to provide novel insights into ways to explore, conceptualize and improve organizational performance. Such an interdisciplinary approach could help identify combinations of high-performing organizational attributes that could lead to the development of a unique and sustainable competitive advantage for a wide variety of organizations in today's increasingly competitive and turbulent world.

As we have indicated in our selective use of examples, many organizations already appear to be doing several of the things we contend neuroanatomy tells us are important for the performance of the brain, suggesting that they are to all intents and purposes already developing the traits of a

neuroorganizational approach – but by default. There is one major and important difference between our examples and the way the brain itself is organized – the brain achieves excellence as a result of *holistic* activity and organization: it consists of a unified and interdependent whole that is greater than the sum of its constituent parts. It is our contention that the core attribute – almost the defining attribute – of a neuroorganizational approach is predicated on a holistic explication whereby an organization of any size and purpose *deliberately chooses* to deploy neuroanatomical principles as the basis for organizing its operations. It is not a ‘pick and mix’ process whereby an organization selects only the bits it thinks are important to improve performance. Rather, it is more likely to be an ‘all or nothing’ assignment, where a truly binary choice in favour of neuroorganizational principles could benefit organizational performance and ultimately survival.

Our goal in writing this paper has not been to provide a set of tools or devise a model ready for immediate implementation in organizations, nor to test such a model. That remains a long-term aim that will require considerable resourcing in future research before becoming a reality. Rather, what we have attempted to do is begin to identify areas of organizational theory and practice where the application of neuroanatomical principles and approaches may be beneficial to the development of high-performing organizations. The ideas and research questions we have identified in each of the five sections of our paper, which are by no means comprehensive or exclusive, are likely to serve as a basis from which to begin exploring the potential of this approach. Taken together, these constitute a core research agenda that focus attention on undertaking novel science-based and empirically-driven research into:

- ‘organizational mapping’ based on neuroanatomical principles;
- the mutual interdependence of ‘doing’ and ‘supporting’ primary roles;
- the separation of high order ‘conscious’ and routine ‘subconscious’ functions;
- resourcing ‘developmental remodelling’; and
- organizational memory, plasticity and ‘creative intelligence’.

Whilst it is likely that some of these will turn out to be more significant than others for organizational research and practice, it is our belief that they will lead to significant developments from both an academic and practical standpoint. Nowhere is this likely to be more applicable than in the area of strategic management, with its focus on strategic awareness, strategic analysis and the management of strategic change – what Stacey (2007) aptly refers to as managing the challenges of dynamic complexity. If strategic management is to face up to these challenges, as well as choosing and implementing strategy, then it does not take much of a leap of faith to recognise the potential contribution that each of these neuroanatomically informed elucidations could make to enhancing an individual organization’s strategic awareness, improving its strategic analysis abilities and making its management of strategic change more efficacious. In addition, our neuroorganizational approach suggests that the conventional ways of exploring the linkages between strategy, strategic management and organizational structure may require a radical re-examination. For example, the discrete structural designs typically identified in the mainstream literature (c.f. Thompson & Martin, 2005) include variants of entrepreneurial, functional, divisional, holding company and/or matrix forms. Whilst it is possible to identify one or more elements of each in many of the high-performing organizations discussed in this paper - including *Virgin Atlantic*, *Southwest*, *JetBlue* and *easyJet* - it is also clear that, at the formal level of organizational design, there appears to be a missing element. What characterises each of these organizations is a focus on a somewhat different organizational structure: one that heightens co-operation over competition and empowerment over bureaucratic or functional control (c.f. Peters & Waterman (1982) - ‘simple form, lean staff’, ‘productivity through people’, ‘simultaneous loose-tight properties’ and an obsession with delayering).

Although the focus of this paper has been on exploring the requirements for a neuroanatomical approach to organizational performance at the level of the individual organization, it is quite possible that such an approach could be transferred to other areas of social research in addition to those outlined previously (e.g., artificial neural networks, neuroeconomics, neuromarketing and organizational cognitive neuroscience). For example, the emergence of highly influential research under the aegis of the ‘new economic geography’, ‘clusters’ and the ‘new economics of competition’ - where critical masses of unusual competitive success in particular sectors of economic activity are concentrated uniquely in local things like knowledge, relationships and motivation (e.g., Silicon Valley) (Porter, 1998; Porter, 2003) – are highly suggestive of the potential applicability of neuroanatomical analysis and exploration. For as Krugman (1998) has aptly put it, critics of economics have argued that the field takes too little account of a set of interrelated possibilities, such as the existence of cumulative processes of change involving ‘circular causation’, the persistent effects of historical accident via ‘path dependence’ and the occasional emergence of discontinuous change (maybe even ‘punctuated

equilibrium'). For the most part, however, such efforts have been forced and relatively unconvincing. In the 'new economic geography', however, such non-linear phenomena emerge absolutely naturally from the most basic models. One potentially exciting development in neuroanatomy that may prove to be particularly useful with regard to such modelling is the fledgling science of 'connectomics', which aims to generate detailed maps of synaptic connectivity – network wiring diagrams - in the brain (Lichtman & Sanes, 2008). Such large-scale circuit reconstruction in the nervous system is getting ever closer, bringing with it numerous, transferable advances in computing technologies and expertise required to map, model and visualise extensive sets of connections and relationships.

In conclusion, a programme of truly interdisciplinary and collaborative research into neuroanatomical applications in organizational research - in areas as diverse as strategic management and organizational design (and possibly beyond) - may ultimately lead to business-ready tools that can be utilised by managers in aspirant high-performing organizations. To the best of our knowledge, this paper represents the first step in undertaking such interdisciplinary and collaborative research.

## REFERENCES

- Adams, D.A., Todd, P.A. and Nelson, R.R. (1993) A comparative-evaluation of the impact of electronic and voice mail on organizational communication. *Information & Management* 24:9-21.
- Ambrose, D. (1995) Creatively intelligent post-industrial organizations and intellectually impaired bureaucracies. *Journal of Creative Behavior* 29(1):1-15.
- Asaro, P. (2006) Working models and the synthetic model: Electronic brains as mediators. *Science Studies* 19:12-34.
- Beer, S. (1972) *Brain of the Firm: The Managerial Cybernetics of Organization*. London: Allen Lane The Penguin Press.
- Boillee, S., Yamanaka, K., Lobsiger, C., Copeland, N., Jenkins, N., Kassiotis, G., Kollias, G. and Cleveland, D. (2006) Onset and progression in inherited ALS determined by motor neurons and microglia. *Science* 312:1389-1392.
- Brown, P. (2004) The evolving role of strategic management development. *Journal of Management Development* 24:209-222.
- Bryman, A. (1992) *Charisma and Leadership in Organizations*. London: Sage.
- Bryman, A. (2004) *The Disneyization of Society*. London: Sage.
- Bryman, A., Gillingwater, D. and McGuinness, I. (1996) Industry culture and strategic response: The case of the British bus industry. *Studies in Cultures, Organizations and Societies* 2:191-208.
- Buenstorf, G. and Witt, U. (2006) How problems of organisational growth in firms affect industry entry and exit. *Revue de l'OFCE* 97:47-62.
- Butler, M.J.R. & Senior, C. (2007) Towards an organizational cognitive neuroscience. In: *The Social Cognitive Neuroscience of Organizations* (Eds: Senior, C. & Butler, M.J.). New York: Annals of the New York Academy of Sciences.
- Camerer, C.F., Loewenstein, G. and Prelec, D. (2004) Neuroeconomics: Why economics needs brains. *Scandinavian Journal of Economics* 106(3):555-579.
- Capodagli, B. and Jackson, L. (1999) *The Disney Way*. New York: McGraw-Hill.
- Catani, M. (2006) Diffusion tensor magnetic resonance imaging tractography in cognitive disorders. *Current Opinion in Neurology* 19:599-606.
- Christensen, C., Suárez, F. and Utterback, J. (1998) Strategies for survival in fast-changing industries. *Management Science* 44:S207-220.
- Christopher, W. (2007) *Holistic Management: Managing What Matters for Company Success*. New York: John Wiley.
- Ciborra, C. (2001a) A critical review of the literature on the management of corporate information infrastructure, (In) Ciborra, C. (Ed) *From Control to Drift: The Dynamics of Corporate Information Infrastructures*. Oxford: Oxford University Press.
- Ciborra, C. (2001b) From Alignment to Loose Coupling: From MedNet to www.roche.com. In: Ciborra, C. (Ed) *From Control to Drift: The Dynamics of Corporate Information Infrastructures*. Oxford: Oxford University Press.
- Combe, I. and Botschen, G. (2004) Strategy paradigms for the management of quality: Dealing with complexity. *European Journal of Marketing* 38:500-523.



- Cooke, S.F. and Bliss, T.V. (2006) Plasticity in the human central nervous system. *Brain* 129:1659-1673.
- Crossman, A.R. and Neary, D. (2005) *Neuroanatomy: An Illustrated Colour Text* (3<sup>rd</sup> Ed.). Oxford: Churchill Livingstone.
- Dahlgaard-Park, S. and Dahlgaard, J. (2007) Excellence – 25 years evolution, *Journal of Management History* 13:371-393.
- Denoyelle, P. and Larreche, J-C. (1995) Virgin Atlantic Airways: 10 years later (and beyond). Case #595-023-1, INSEAD France, Fontainebleau.
- Dewar, D., Yam, P. and McCulloch, J. (1999) Drug development for stroke: Importance of protecting cerebral white matter. *European Journal of Pharmacology* 375:41-50.
- Disney Institute (2001) *Be Our Guest: Perfecting the Art of Customer Service*. New York: Disney Editions.
- Edvardsson, B. and Enquist, B. (2002) ‘The IKEA saga’: How service culture drives service strategy. *Services Industry Journal* 22:153-186.
- Eppler, M. and Mengis, J. (2004) The concept of information overload: A review of literature from organization science, accounting, marketing, MIS, and related disciplines. *The Information Society* 20:325-344.
- Feldman, R.M. and Feldman, S.P. (2006) What links the chain: An essay on organizational remembering as practice. *Organization* 13:861-887.
- Ferguson, B., Matyszak, M.K., Esiri, M.M. and Perry, V.H. (1997) Axonal damage in acute multiple sclerosis lesions. *Brain* 120:393-399.
- Fiorini, F. (2002) JetBlue pursues growth while staying ‘small’. *Aviation Week & Space Technology* 156:41-43.
- Flouris, T. and Oswald, S. (2006) *Designing and Executing Strategy in Aviation Management*. Aldershot: Ashgate.
- Freedman, M. (2003) The genius is in the implementation. *Journal of Business Strategy* March/April:26-31.
- Freeman, M.R. (2006) Sculpting the nervous system: Glial control of neuronal development. *Current Opinion in Neurobiology* 16:119-125.
- Garud, R. and Kotha, S. (1994) Using the brain as a metaphor to model flexible production systems. *Academy of Management Review* 19:671-698.
- Gittell, J. (2003) *The Southwest Airlines Way: Using the Power of Relationships to Achieve High Performance*. New York: McGraw-Hill.
- Greiner, L. (1998) Evolution and revolution as organizations grow. *Harvard Business Review* 76:55-67.
- Grinyer, P., Mayes, D. and McKiernan, P. (1989) *Sharpbenders: The Secrets of Unleashing Corporate Potential*. Oxford: Blackwell.
- Hall, W. (1980) Survival strategies in a hostile environment. *Harvard Business Review* 58:75-85.
- Harari, O. (1994) The brain-based organization. *Management Review* 83:57-60.
- Hart, S. (1992) An integrative framework for strategy-making processes. *Academy of Management Review* 17:327-351.
- Hart, S. and Banbury, C. (1994) How strategy-making processes can make a difference. *Strategic Management Journal* 15:251-269.
- Hatch, M. and Cunliffe, A. (2006) *Organization Theory: Modern, Symbolic, and Postmodern Perspectives* (2<sup>nd</sup> Ed.). Oxford: Oxford University Press.
- Hensch, T.K. (2005) Critical period plasticity in local neocortical circuits. *Nature Reviews Neuroscience* 6:877-888.
- Johnson, G. (1988) Rethinking incrementalism. *Strategic Management Journal* 9:75-91.
- Kaplan, R. and Norton, D. (2000) Having trouble with your strategy? Then map it. *Harvard Business Review* September-October: 3-11.
- Kim, T., Oh, H. and Swaminathan, A. (2006) Framing interorganizational network change: A network inertia perspective. *Academy of Management Review* 31:704-720.
- Kim, W.C. and Mauborgne, R. (1999) Strategy, value innovation, and the knowledge economy. *Sloan Management Review* Spring:41-54.

- Klein, J. (1990) *Interdisciplinarity: History, Theory and Practice*. Detroit: Wayne State University Press.
- Kotler, P. (1999) *Kotler on Marketing*. New York: Free Press.
- Kriegstein, A., Noctor, S. and Martinez-Cerdeno, V. (2006) Patterns of neural stem and progenitor cell division may underlie evolutionary cortical expansion. *Nature Reviews Neuroscience* 7:883-890.
- Krugman, P. (1998) What's new about the new economic geography? *Oxford Review of Economic Policy* 14:7-17.
- Kumar, N. (2004) *Marketing as Strategy: Understanding the CEO's Agenda for Driving Growth and Innovation*. Boston: Harvard Business School Press.
- Kuemmerle, W. (1999) Commentary 3: easyJet: Big ticket entrepreneurship. *European Management Journal* 17:36-37.
- Larsen, M. and Leinsdorff, T. (1998) Organizational learning as a test-bed for business process reengineering, *Proceedings of the 31<sup>st</sup> Hawaii International Conference on System Sciences*, 6-9 January, 5:343-354.
- Lee, N., Broderick, A. and Chamberlain, L. (2007) What is 'neuromarketing'? A discussion and agenda for future research. *International Journal of Psychophysiology* 63:199-204.
- Lester, D. (2004) Organisational life cycle stage and strategy: must they match? *International Journal of Management and Decision Making* 5:135-143.
- Lichtman, J.W., Livet, J. and Sanes, J.R. (2008) A technicolour approach to the connectome. *Nature Reviews Neuroscience* 9:417-422.
- Lichtman, J.W. and Sanes, J.R. (2008) Ome sweet ome: What can the genome tell us about the connectome? *Current Opinion in Neurobiology* 18:346-353.
- Lievens, A. and Moenaert, R.K. (2000) Project team communication in financial service innovation. *Journal of Management Studies* 37:733-766.
- Liker, J. (2004) *The Toyota Way*. New York: McGraw-Hill.
- Lippitt, G.L. and Schmidt, W.H. (1967) Crises in a developing organization. *Harvard Business Review* 45:102-112.
- Low, L.K. and Cheng, H.J. (2006) Axon pruning: an essential step underlying the developmental plasticity of neuronal connections. *Philosophical Transactions of the Royal Society Part B* 361:1531-1544.
- Mankins, M. and Steele, R. (2005) Turning great strategy into great performance. *Harvard Business Review* 83:65-72.
- Marshall, G.W., Michaels, C.E. and Mulki, J.P. (2007) Workplace isolation: Exploring the construct and its measurement. *Psychology & Marketing* 24:195-223.
- Maurer, D. and Lewis, T.L. (2001) Visual acuity: The role of visual input in inducing postnatal change. *Clinical Neuroscience Research* 1:239-247.
- Maurer, D., Lewis, T.L. and Mondloch, C.J. (2005) Missing sights: Consequences for visual cognitive development. *Trends in Cognitive Sciences* 9:144-151.
- McCabe, K. (2003) Neuroeconomics. (In) Nadel, L., (Ed) *Encyclopedia of Cognitive Science*. New York: Macmillan.
- McKnight, L., Vaaler, P. and Katz, R. (Eds) (2001) *Creative Destruction: Business Survival Strategies in the Global Internet Economy*. Boston: MIT Press.
- Melis, M., Spiga, S. and Diana, M. (2005) The dopamine hypothesis of drug addiction: Hypodopaminergic state. *International Review of Neurobiology* 63:101-154.
- Miller, D. and Friesen, P.H. (1980) Momentum and revolution in organizational adaptation. *Academy of Management Journal* 23:591-614.
- Mitchell, A. (1999) Out of the shadows. *Journal of Marketing Management* 15:25-42.
- Monteiro, E. and Hepso, V. (2001) Infrastructure strategy formation: Seize the day at Statoil. In: Ciborra, C. (Ed) *From Control to Drift: The Dynamics of Corporate Information Infrastructures*. Oxford: Oxford University Press.
- Morgan, G. (2006) *Images of Organization* (Updated ed.). London: Sage.

- Nagai, M., Re, D.B., Nagata, T., Chalazonitis, A., Jessell, T.M., Wichterle, H. and Przedborski, S. (2007) Astrocytes expressing ALS-linked mutated SOD1 release factors selectively toxic to motor neurons. *Nature Neuroscience* 10:615-622.
- Nicholson, N., Rees, A. and Brooks-Rooney, A. (1990) Strategy, innovation and performance. *Journal of Management Studies* 27:511-534.
- Nonaka, I. & Takuchi, H. (1995) *The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation*. New York: Oxford University Press.
- Pauwels, P. and Matthyssens, P. (2003) The dynamics of international market withdrawal. In: Jain, S. (Ed) *Handbook of Research in International Marketing*. Cheltenham: Edward Elgar.
- Peters, T. and Waterman, R. (1982) *In Search of Excellence: Lessons from America's Best-Run Companies*. London: HarperCollins.
- Peterson, B. and Glab, J. (1995) *Rapid Descent: Deregulation and the Shakeout in the Airlines*. New York: Simon and Schuster.
- Porter, M.E. (1998) Clusters and the new economics of competition. *Harvard Business Review* Nov-Dec: 77-90.
- Porter, M.E. (2003) The economic performance of regions. *Regional Studies* 37:549-578.
- Quinn, R.E. and Cameron, K. (1983) Organizational life cycles and shifting criteria of effectiveness: Some preliminary evidence. *Management Science* 29:33-51.
- Rae, D. (2001) EasyJet: A Case of Entrepreneurial Management? *Strategic Change* 10:325-336.
- Schmahmann, J. D. (2003) Vascular syndromes of the thalamus. *Stroke* 34:2264-2278.
- Senior, C. & Butler, M.J.R. (Eds) (2007) *The Social Cognitive Neuroscience of Organizations*. New York: Annals of the New York Academy of Sciences (1118).
- Sherman, D.L. and Brophy, P.J. (2005) Mechanisms of axon ensheathment and myelin growth. *Nature Reviews Neuroscience* 6:683-690.
- Smolensky, M. & Stein, E. (Eds) (1998) *Human Factors in Air Traffic Control*. San Diego: Academic Press.
- Stacey, R.D. (2007) *Strategic Management and Organisational Dynamics: The Challenge of Complexity to Ways of Thinking About Organisations*. Harlow: Financial Times/Prentice-Hall.
- Stadler, C. (2007) The four principles of enduring success. *Harvard Business Review* 85:62-72.
- Straus, B. (2009) Neeleman out as JetBlue CEO. *Air Transport World*, 11<sup>th</sup> May. (Accessed March 2009: [www.atwonline.com/news/story.html?storyID=8864](http://www.atwonline.com/news/story.html?storyID=8864))
- Sull, D. (1999) Case study: easyJet's \$500 million gamble. *European Management Journal* 17:20-32.
- SWA (2009) Customer service commitment. *Southwest Airlines*, Dallas TX. (Accessed March 2009: [www.southwest.com/about\\_swa/customer\\_service\\_commitment/customer\\_service\\_commitment.pdf](http://www.southwest.com/about_swa/customer_service_commitment/customer_service_commitment.pdf))
- Tegarden, D.P. and Sheetz, S.D. (2003) Group cognitive mapping: a methodology and system for capturing and evaluating managerial and organizational cognition. *Omega* 31:113-125.
- Thompson, J.L. and Martin, F. (2005) *Strategic Management: Awareness, Analysis and Change*. (5<sup>th</sup> ed). London: Thomson Learning.
- Trachtenberg, J.T., Chen, B.E., Knott, G.W., Feng, G., Sanes, J.R., Welker, E. and Svoboda, K. (2002) Long-term in vivo imaging of experience-dependent synaptic plasticity in adult cortex. *Nature* 420:788-794.
- VAA (2009) Welcome to the Virgin Atlantic careers site. *Virgin Atlantic Airways*, Crawley. (Accessed March 2009: <http://www.virgin-atlantic.com/en/gb/careers/index.jsp>)
- Van de Ven, A.H. (1980) Early Planning, Implementation, and Performance of New Organizations. In: *The Organizational Life Cycle* (Eds: Kimberly, J. & Miles, R.). San Francisco: Jossey-Bass.
- Venkatraman, N. and Ramanujam, V. (1986) Measurement of business performance in strategy research: A comparison of approaches. *Academy of Management Review* 11:801-814.
- Virgin Group (2009) About Virgin: What we are about. *Virgin Group*, London. (Accessed March 2009: <http://www.virgin.com/AboutVirgin/WhatWeAreAbout/>)
- Vrecko, S. (2008) Capital ventures into biology: Biosocial dynamics in the industry and science of gambling. *Economy and Society* 37:50-67.

- Wakana, S., Jiang, H., Nague-Poetscher, L.M., van Zijl, P.C. and Mori, S. (2004) Fiber tract-based atlas of human white matter anatomy. *Radiology* 230:77-87.
- Walsh, J.P. and Ungson, G.R. (1991) Organizational memory. *Academy of Management Review* 16:57-91.
- Wilson, H., Daniel, E. and McDonald, M. (2002) Factors for success in customer relationship management (CRM) systems. *Journal of Marketing Management* 18:193-219.
- Wishart, T.M., Parson, S.H. and Gillingwater, T.H. (2006) Synaptic vulnerability in neurodegenerative disease. *Journal of Neuropathology and Experimental Neurology* 65:733-739.
- Wolpaw, J.R. (2006) The education and re-education of the spinal cord. *Progress in Brain Research* 157:261-280.
- Womack, J., Jones, D. and Roos, D. (2007) *The Machine That Changed the World: The Story of Lean Production - Toyota's Secret Weapon in the Global Car Wars That Is Now Revolutionizing World Industry* (2<sup>nd</sup> ed.). New York: Simon & Schuster.
- Wyatt, R.M. and Balice-Gordon, R.J. (2003) Activity-dependent elimination of neuromuscular synapses. *Journal of Neurocytology* 32:777-794.
- Wynbrandt, J. (2004) *Flying High*. New York: John Wiley.